Chemical Reactions and Energy Calculations

Learning Outcomes

1. Calculate formal weights and molecular weights.

2. Identify balanced chemical equations.

3. Write balanced chemical equations

Calculating Formula Mass: Mass of a Molecule or Formula Unit

$$\text{formula mass} = \left(\boxed{\begin{array}{c}\text{\# atoms of 1st}\\ \text{element in}\\ \text{chemical formula}\end{array}} \times \boxed{\begin{array}{c}\text{atomic mass}\\ \text{of}\\ \text{1st element}\end{array}} \right) + \left(\boxed{\begin{array}{c}\text{\# atoms of 2nd}\\ \text{element in}\\ \text{chemical formula}\end{array}} \times \boxed{\begin{array}{c}\text{atomic mass}\\ \text{of}\\ \text{2nd element}\end{array}} \right) + \ldots$$

What is the mass (in amu) of one molecule of BF_3?

$$m_{\mathrm{BF_3}} = a \cdot m_{\mathrm{B}} + b \cdot m_{\mathrm{F}}$$

$$m_{\mathrm{BF_3}} = 1 \cdot m_{\mathrm{B}} + 3 \cdot m_{\mathrm{F}}$$

$$m_{\mathrm{BF_3}} = (1)\,(10.81\ \mathrm{amu}) + (3)\,(19.00\ \mathrm{amu})$$

$$m_{\mathrm{BF_3}} = 67.81\ \mathrm{amu}$$

Problem 1

What is the mass (in amu) for one water molecule?

Problem 2

What is the mass (in amu) for one molecule of carbon dioxide?

Problem 3

What is the formal weight (in amu) for NaCl?

Molecular and Empirical Formulas

Molecular Formula: Gives the exact number of atoms that make up a molecule.

Empirical Formula: Gives the ratio of atoms to one another in a molecule.

Problem 4

The molecular formula for hydrogen peroxide is H_2O_2. What is the empirical formula?

Browning of Food

Créme Brûlée

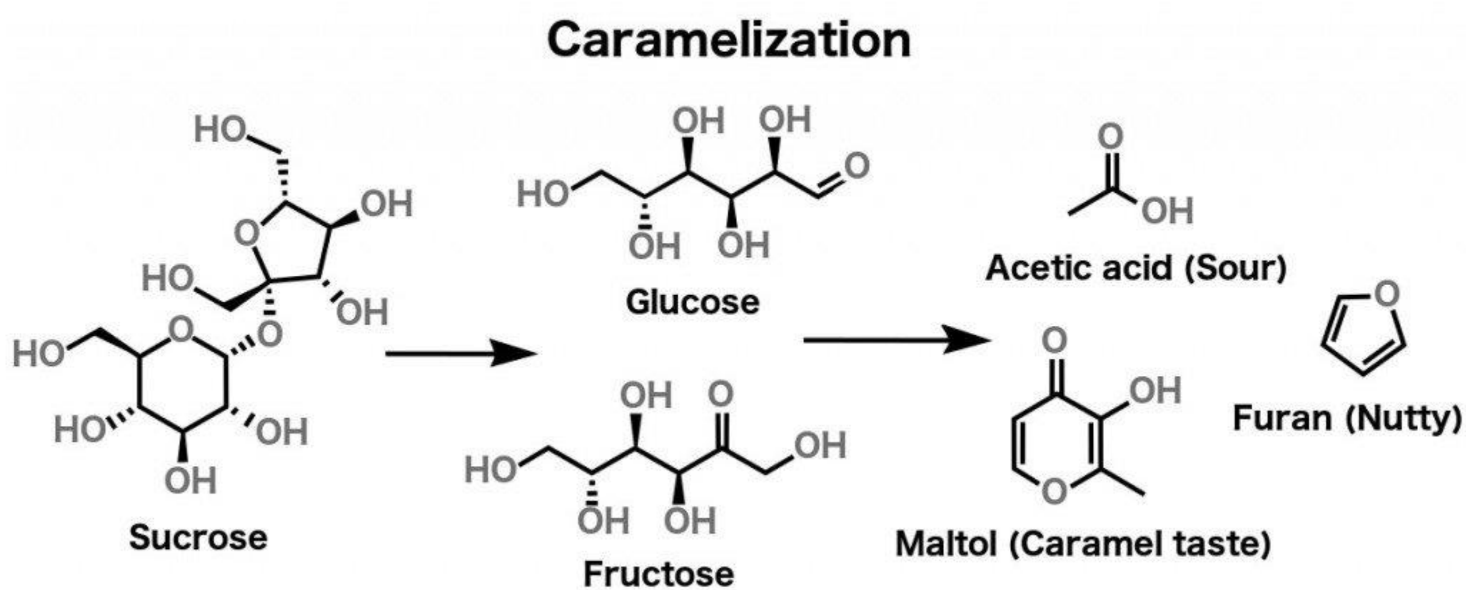
Browning of Food

Onions

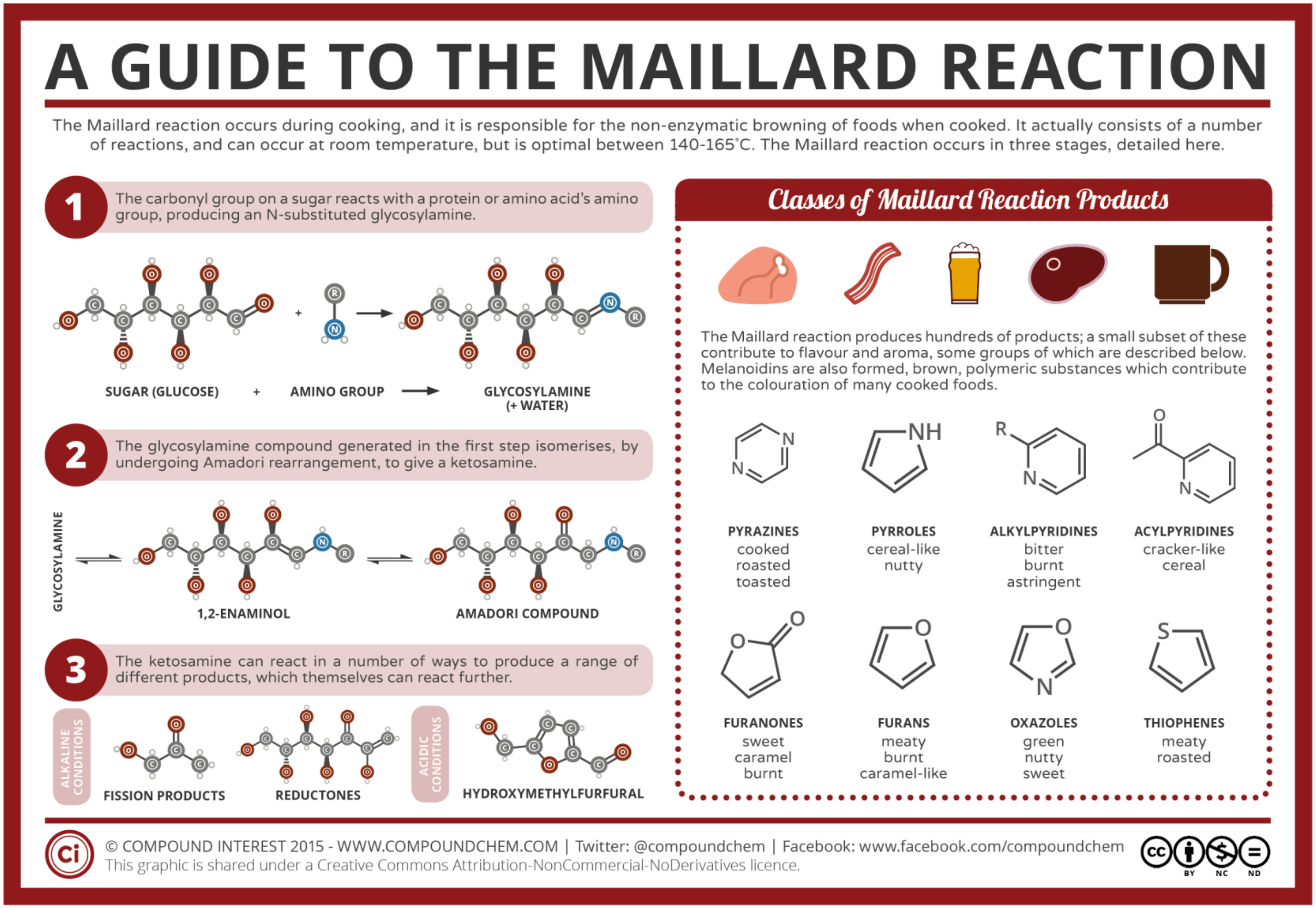
Browning of Food

Sugar

Caramelization



Maillard Reaction



Physical and Chemical Changes

A ***physical change*** is a change that alters only the state or appearance of matter, but not its composition. A ***chemical change*** is a change that alters the composition of matter.

Quartz!!

Physical Change

Silver Spoon!!

Silver (Ag)

Chemical Change

Silver(II) Oxide (Ag_2O)

Physical and Chemical Changes

Physical Change

Chemical Reaction

Chemical Equations: Banana Split!

$$\text{Reactants} \longrightarrow \text{Products}$$

Chemical Equations Indicate the State of Matter

State	Symbol
s	Solid
l	Liquid
g	Gas
aq	Aqueous (Ions Dissolved In Water)

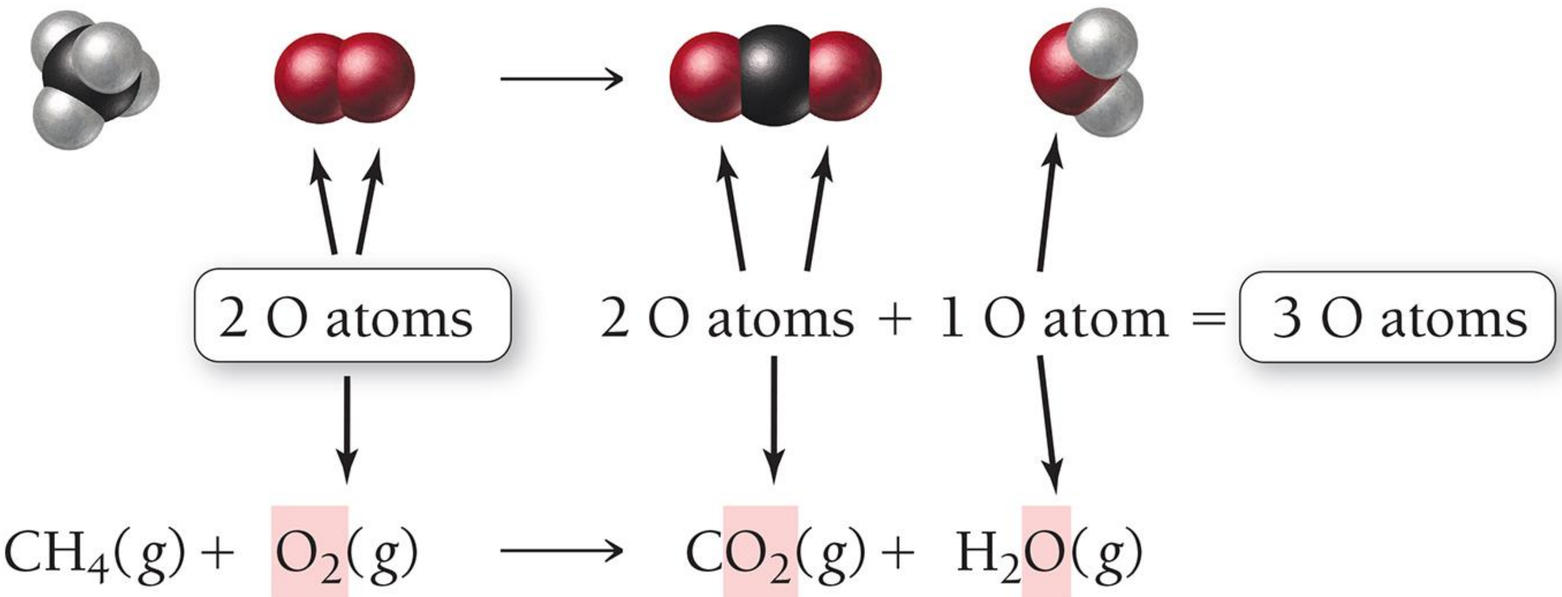
Balancing Chemical Equations: Banana Split!

$$\text{Reactants} \longrightarrow \text{Products}$$

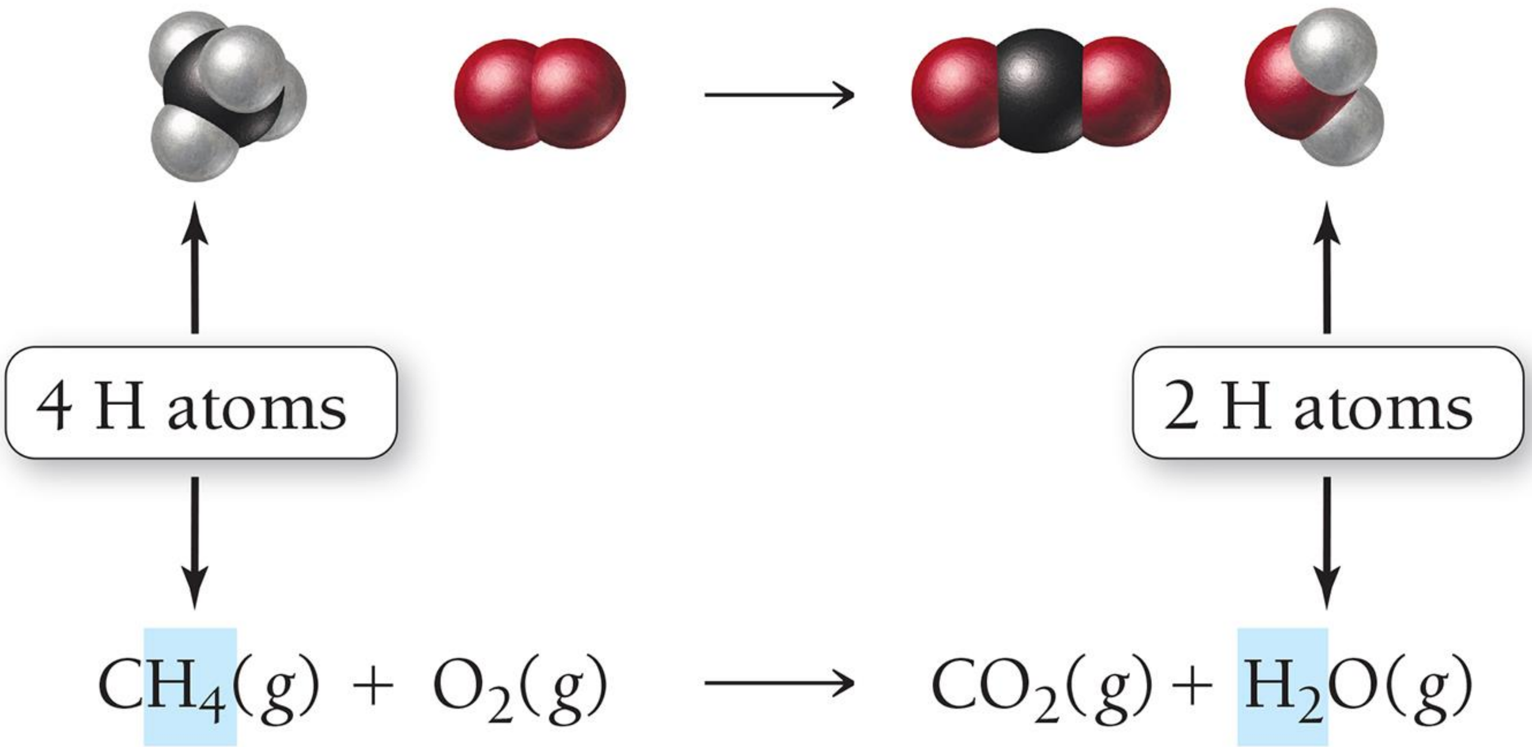
$$\text{Banana}\,(s) + \text{Ice Cream Scoop}\,(s) \longrightarrow \text{Banana Split}\,(s)$$

$$1\ \text{Banana}\,(s) + 3\ \text{Ice Cream Scoops}\,(s) \longrightarrow 1\ \text{Banana Split}\,(s)$$

Balancing Chemical Equations



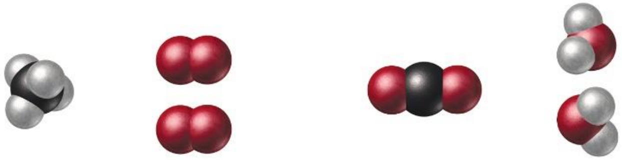
Balancing Chemical Equations



Balancing Chemical Equations

$$CH_4(g) + \mathbf{2}\ O_2(g) \longrightarrow CO_2(g) + \mathbf{2}\ H_2O(g)$$

What Does it Mean to Balance?



$CH_4(g) + \mathbf{2}\ O_2(g) \longrightarrow CO_2(g) + \mathbf{2}\ H_2O(g)$

Balancing Chemical Equations Time!

Balancing chemical equations time!

Problem 5

Balance the following chemical equation for the oxidation of ethanol:

$$CH_3CH_2OH(l) + O_2(g) \rightarrow CH_3COOH(aq) + H_2O(l)$$

Problem 6

Balance the following chemical equation for photosynthesis:

$$CO_2(g) + H_2O(l) \rightarrow O_2(g) + C_6H_{12}O(aq)$$

Problem 7

Balance the following chemical equation for the combustion of methane:

$$CH_4(g) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$$

Problem 8

Balance the following chemical equation for the rusting of iron:

$$Fe(s) + O_2(g) \rightarrow Fe_2O_3(g)$$

Learning Outcomes

1. Explain what a mole is and why it is used.
2. Recognize the numerical relationship between chemical quantities in a balanced chemical equation.
3. Use the molar mass to convert between mass and mole.
4. Use Avogadro's number to convert between amount and mole.
5. Convert between grams of a compound and grams of another compound.

Problem 9

What unit of measured is used to purchase the following:

(a) Gasoline

(b) Meat

(c) Gold

Problem 10

Define how many dozen of the following objects you have. Use dimensional analysis and show all units.

(a) 12 eggs

(b) 24 paper sheets

(c) 18 cupcakes

Problem 11

Ran the following in order of increasing number:

5 dozen quarters, 12 dozen cattle, 3.5 dozen movies

Problem 12

Select the dozen that weighs more:

(a)

Eggs or Cats

(b)

Sand Grains or Tennis Balls

Problem 13

Select the grouping that has more particles.

(a)

A gallon of marbles or a gallon of sand

(b)

25 mL of water or 25 mL of corn kernels

Problem 14

1 L of water contains 3.34×10^{25} molecules. Do you think a dozen is a good way to group the number of water molecules? Explain.

What is a Mole?

Mole Definition

A mole is a "chemist's" dozen!

Just as 1 dozen = 12 of anything,

1 mole = 6.023×10^{23} of anything

Avogadro's Number

$$N_{\mathrm{A}} = \frac{6.023\times10^{23}\ \text{units}}{1\ \text{mole units}}$$

A Mole Can Be Anything!!

1 dozen cats = 12 cats,

1 mole cats = 6.023×10^{23} cats

Chemical Equations Revisited

How many iron ***atoms*** are needed to prepare two ***formula units*** of iron oxide?

$$4\ Fe(s) + 3\ O_2(g) \rightarrow\ 2\ Fe_2O_3(g)$$

Problem 15

What is the mass of 4 iron atoms. Note, m_{Fe} = 55.85 amu and 1 amu = 1.66×10^{-24} g.

Chemical Equations Revisited

How many ***dozens*** of iron ***atoms*** are needed to prepare two ***dozen*** ***formula units*** of iron oxide?

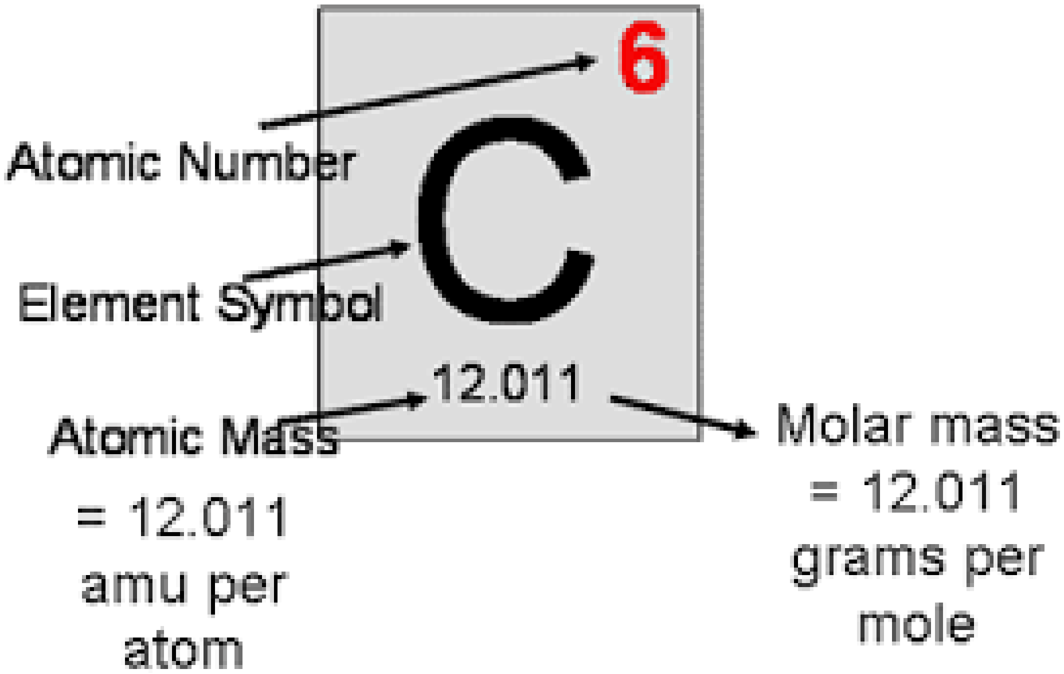
$$4\ Fe(s) + 3\ O_2(g) \rightarrow 2\ Fe_2O_3(g)$$

Chemical Equations Revisited

How many ***moles*** of iron ***atoms*** are needed to prepare two ***moles*** of iron oxide?

$$4\ Fe(s) + 3\ O_2(g) \rightarrow\ 2\ Fe_2O_3(g)$$

Why Do the Elements Not Have Units for the Mass on the Periodic Table?

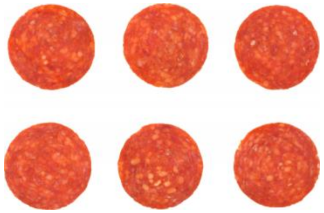


Problem 16

What is the mass of 4 moles of iron. Note, m_{Fe} = 55.85 g/mol.

A Recipe is a Source of Ratios

1 Pizza Dough Round + 31 Pepperoni Slices + 2 Olive Slices + 250 Cheese Shreds $\longrightarrow$ Pizza



A Recipe is a Source of Ratios

$$1 \text{ Pizza Dough Round} + 31 \text{ Pepperoni Slices} + 2 \text{ Olive Slices} + 250 \text{ Cheese Shreds} \longrightarrow \text{Pizza}$$

1 Pizza Dough Round : 31 Pepperoni Slices

2 Olive Slices : 250 Cheese Shreds

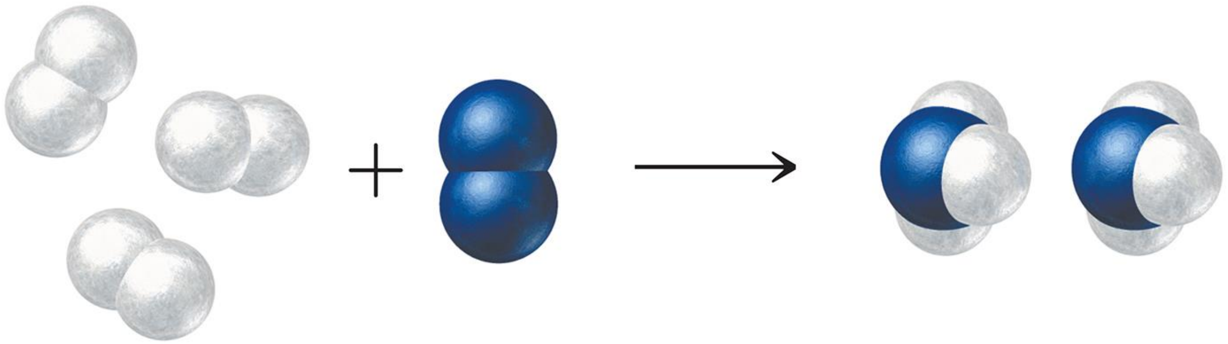
1 Pizza Dough Round : 1 Pizza

2 Olive Slices : 1 Pizza

Problem 17

What ratios can be gathered from the following chemical equation?

$$3\,H_2\,(g) + N_2\,(g) \longrightarrow 2\,NH_3\,(g)$$

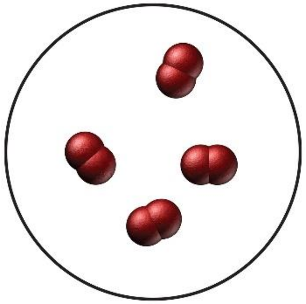


A chemical equation is a recipe of ratios!

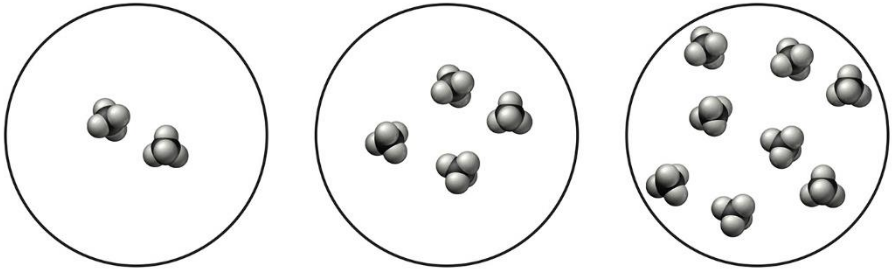
Problem 18

Methane (CH_4) undergoes combustion according to the following reaction:

$$CH_4\,(g) + 2\,O_2\,(g) \longrightarrow CO_2\,(g) + 2\,H_2O\,(g)$$



If the figure above represents the amount of oxygen available to react, which of the following figures best represents the amount of CH_4 required to completely react with all of the oxygen?



(a) (b) (c)

Problem 19

Calculate how many moles of HCl form when 1.75 mol of H_2 reacts with Cl_2. You may assume that there is excess Cl_2.

$$H_2\,(g) + Cl_2\,(g) \longrightarrow 2\,HCl$$

Problem 20

Calculate how many grams of MgO form when 2.4 g of Mg reacts with O_2. You may assume that there is excess O_2.

$$2\,\mathrm{Mg\,(s)} + \mathrm{O_2\,(g)} \longrightarrow 2\,\mathrm{MgO\,(s)}$$

Problem 21

Calculate how many grams of NaOH form when 2.4 g of Na_2O reacts with H_2O. You may assume that there is excess H_2O.

$$\mathrm{Na_2O\,(s) + H_2O\,(l) \longrightarrow 2\,NaOH\,(aq)}$$